
VISITANTE
3M
It’s quite clear we need some more geochemistry here


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- **Assessment of previous work especially mapping, data, stable isotopes and fluid inclusions by Vieira, Ribeiro-Rodrigues, Xavier; geochronology by Noce and Tassinari; general geology of the region e.g. Lobato et al. 2001a, b**
- **Underground sampling and mapping key features (Cuiabá), core logging and sampling (Cuiabá, Lamego, Raposos, Morro Velho), petrography, microprobe analysis of carbonates**
- **Petrography, mineral chemistry and wholerock geochemistry pertinent to ore genesis and exploration**
- **Stable isotope geochemistry**
- **Zircon U-Pb geochronology of cover sequences (Moeda and Maquine quartzites)**
- **Ar-Ar in pyrite geochronology of syn-ore basalt alteration**
- **Monazite U-Pb geochronology in cover sequence clastics**
- **geochemical modelling of ore genesis scenarios**
- **Fusion with local and regional structural models**
- **Development of ore genesis model by fusion of the above with regional and mine scale structural work**

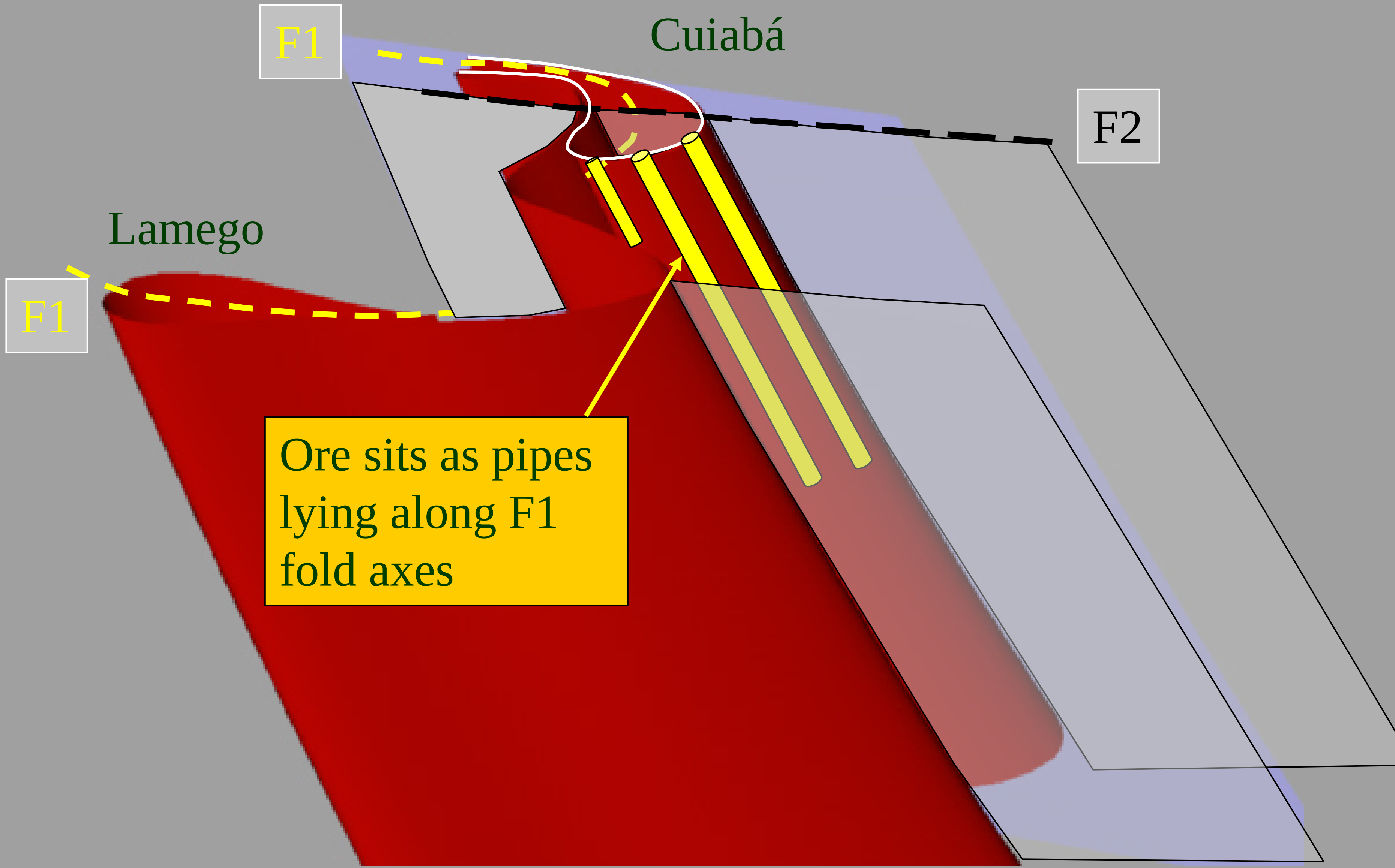
Geochemical Analysis

What do I do with this?

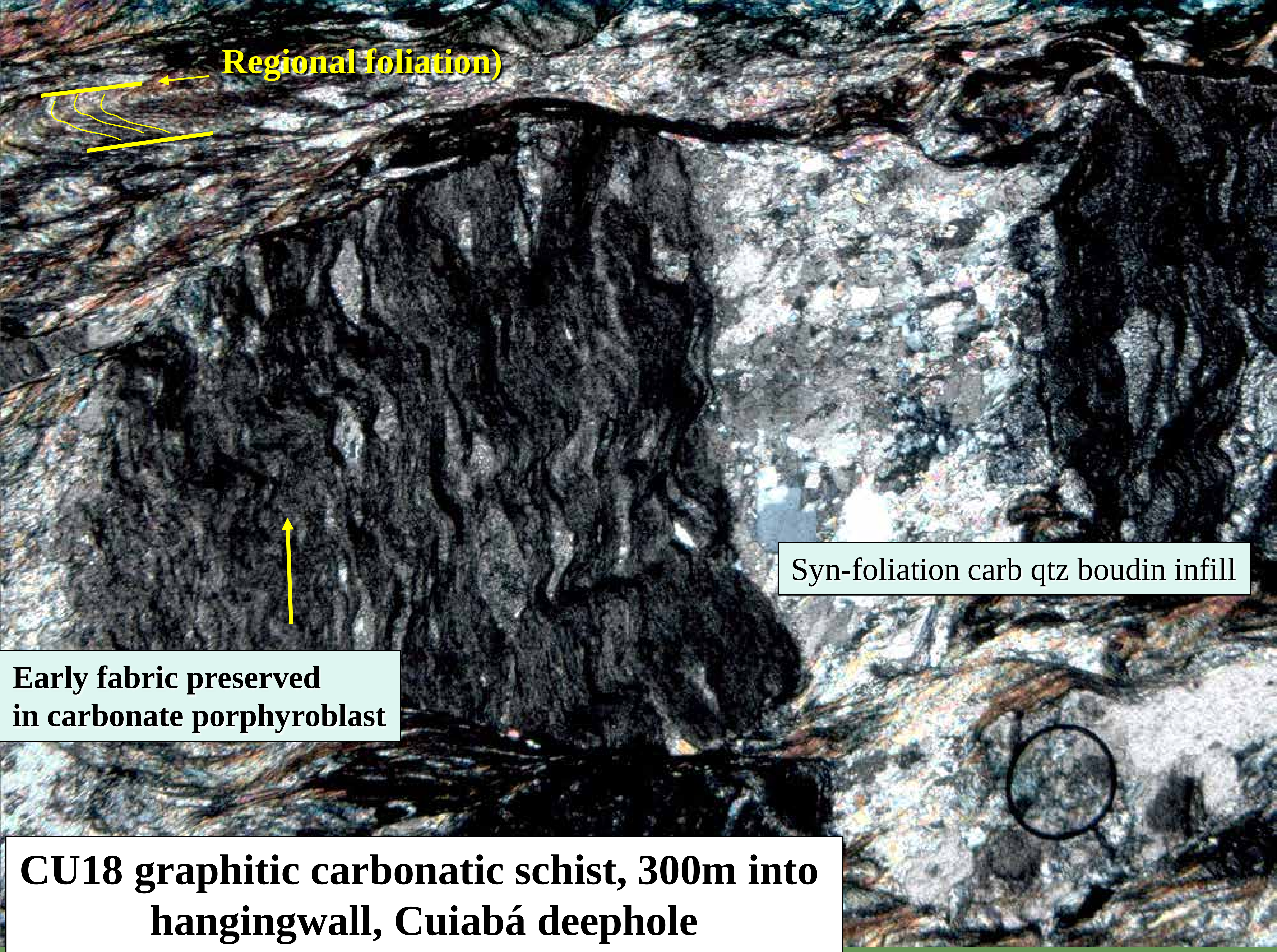
PH05017766 - Finalized
CLIENT : "JAMCOOTV - James Cook University (Townsville)"
# of SAMPLES : 27
DATE RECEIVED : 2005-03-10 DATE FINALIZED : 2005-04-08
PROJECT : "Anglogold Brazilian"
CERTIFIC/ ICP-AES results shown. REE's may not be totally soluble in MS61 method."
PO NUMBER : "Per email request D Foster"

	Au-AA24	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61
SAMPLE	Au	Ag	Al	As	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr	Cs	Cu
DESCRIPT	ppm	ppm	%	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm
CU-74	<0.005	0.18	9.56	5.7	10	0.32	0.05	4.61	0.09	9.5	58.4	207	0.12	51.4
CU-75	0.005	0.22	8.87	4.7	20	0.25	0.04	4.83	0.1	14.5	62.7	225	0.11	26.7
CU-76	<0.005	0.26	9.08	22.6	60	0.26	0.04	2.75	0.1	9.68	58.5	218	0.25	112.5
CU-77a	0.045	0.25	7.33	21.3	500	1.3	0.3	3.78	2.13	40.1	44.4	261	3.18	75.6
CU-77b	<0.005	0.21	8.34	67.5	180	0.91	0.03	1.45	0.06	27.4	65.7	252	3.17	73.7
CU-78a	0.137	2.07	6.93	497	230	2.25	2.88	1.96	27.2	68.1	101	259	4.06	234
CU-78b	0.072	1.48	10.35	22.8	360	3.59	1.04	2.21	10.05	111.5	53.4	316	8.43	245
CU-79a	3.84	0.45	0.17	>10000	10	0.24	0.17	4.04	0.11	2.05	41.1	<1	0.09	10.4
CU-79b	1.19	0.25	0.25	2150	<10	0.08	0.11	8.6	0.1	2.62	21.2	26	0.09	152
CU-81a	<0.005	0.18	6.73	59	440	0.85	0.07	4.02	0.1	44.3	48.1	70	4.04	72.3
CU-81b	<0.005	0.14	6.55	56.5	80	0.77	0.04	5.22	0.06	18.2	32	59	2.84	48.2
CU-81c	0.009	0.15	5.15	47.2	40	0.5	0.05	9.07	0.06	18.85	38.3	46	1.74	69.6
CU-81d	<0.005	0.1	0.79	30	40	0.1	0.02	26.3	0.1	7.24	8	<1	0.39	0.2
MV-13d	0.05	0.61	3.01	369	120	0.61	0.59	7.03	0.13	53.8	40.4	148	2.13	243
MV-14a	0.007	0.12	2.67	110	10	0.23	0.12	14.1	0.09	8.56	13	97	0.18	2.7
MV-14b	<0.005	0.14	7.67	234	40	0.64	0.1	4.76	0.08	27.8	38.1	359	2.25	1.4
MV-14c	0.275	0.31	4.23	1145	10	0.2	0.33	0.77	0.06	20.4	16.8	142	0.23	76.8

Exploration geochemistry is only truly useful if it is placed in the context of a comprehensive understanding of the geochemistry of the ore forming system



Structural model of Holcombe et al: refolded folds
(strains too low to support sheath fold model for Cuiabá)



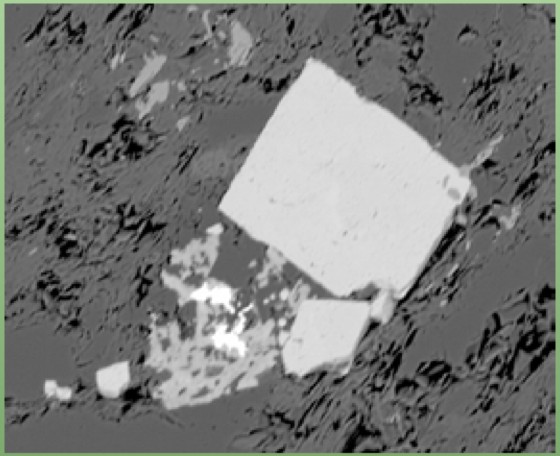
CU18 graphitic carbonatic schist, 300m into hangingwall, Cuiabá deephole

Geochronology – Iron Quadrangle

- **Pyrite-white mica from mineralized footwall basalt at Cuiabá (Ar-Ar in pyrite, timing of ore-proximal alteration and sulphides)**

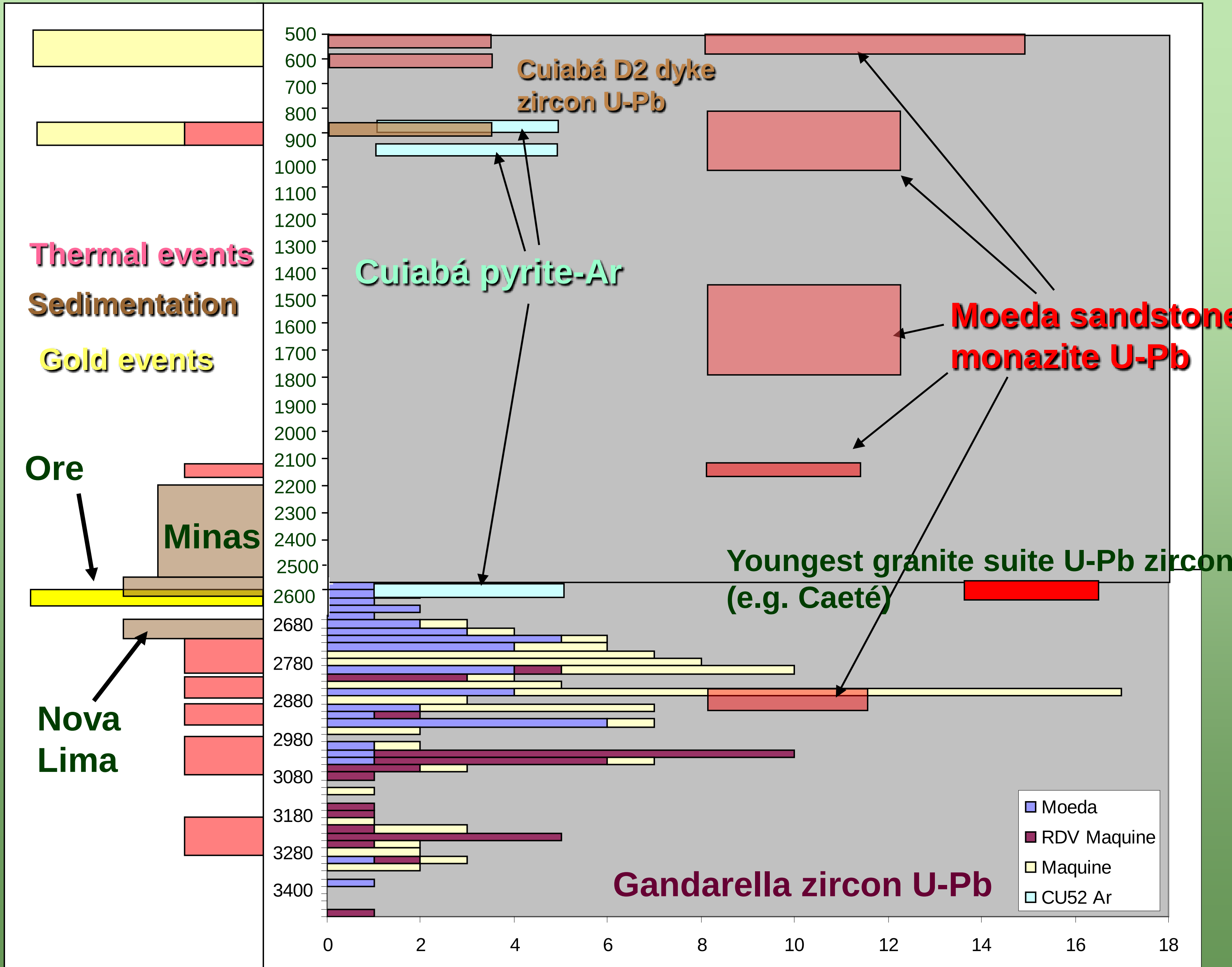
Geochronology – Iron Quadrangle

U-Pb SHRIMP (zircon) on overlying sandstones (Moeda and Maquine) and on mafic dyke cutting ore at Cuiabá (April Pickard, Mark Barley, UWA)



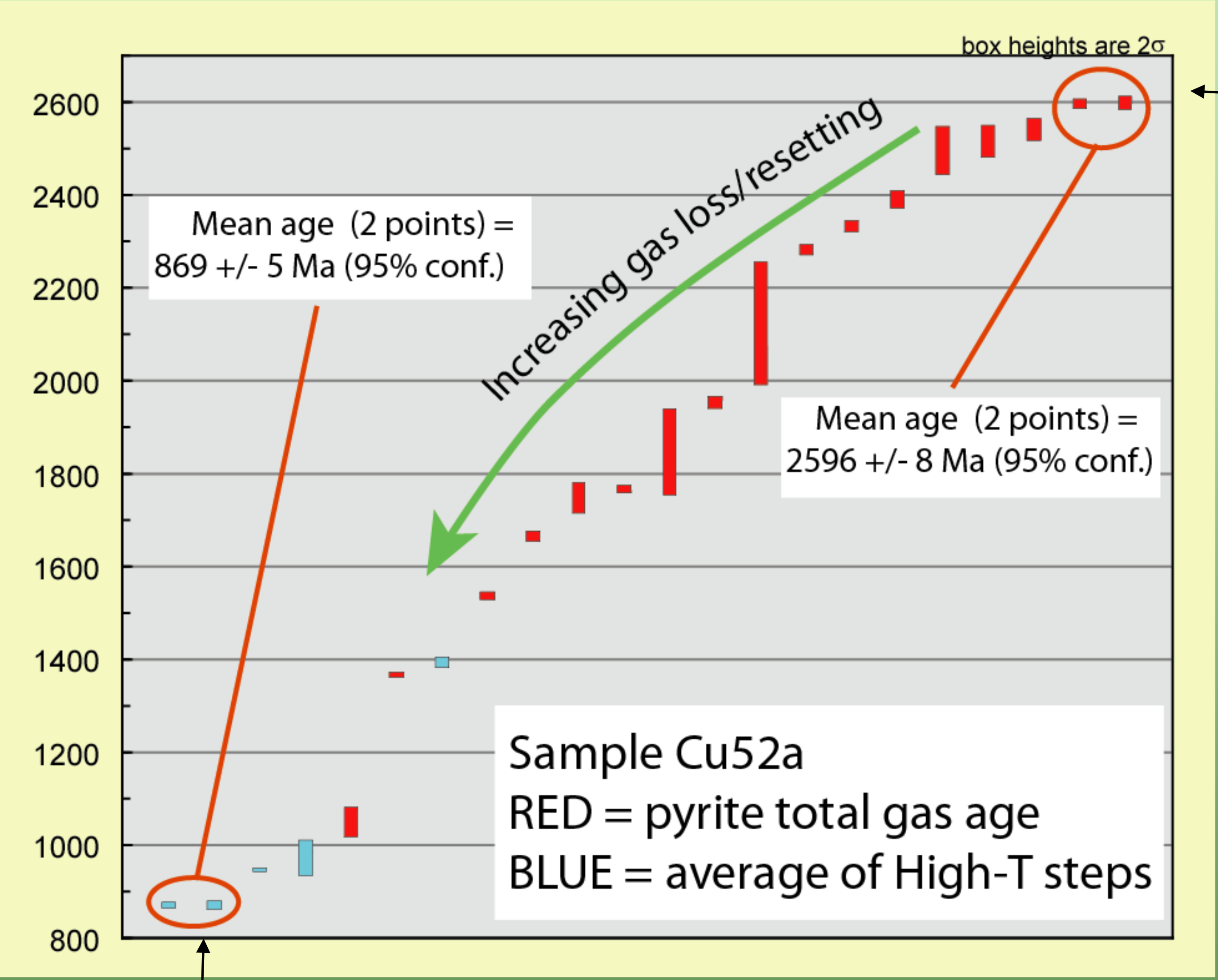
U-Pb EMPA (monazite) on same sandstones (Paul Evins, JCU)

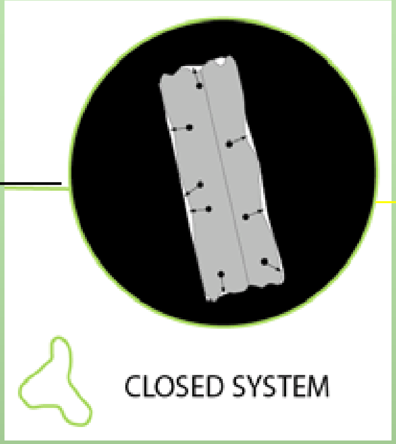
Laser ablation Ar-Ar on alteration-related white mica included in ore minerals (John Miller, Dave Phillips, U. Melb)

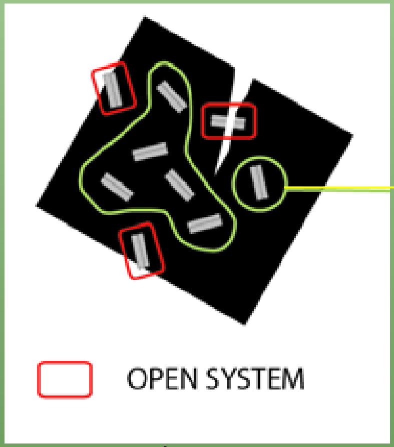


Thermal events
Sedimentation
Gold events
Ore
Minas
Nova Lima
Cuiabá D2 dyke zircon U-Pb
Cuiabá pyrite-Ar
Moeda sandstone monazite U-Pb
Youngest granite suite U-Pb zircon (e.g. Caeté)
Gandarella zircon U-Pb
Moeda
RDV Maquine
Maquine
CU52 Ar
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
2680
2780
2880
2980
3080
3180
3280
3400
0
2
4
6
8
10
12
14
16
18

White mica included in pyrrhotite from mineralized footwall basalt: Ar-Ar dates

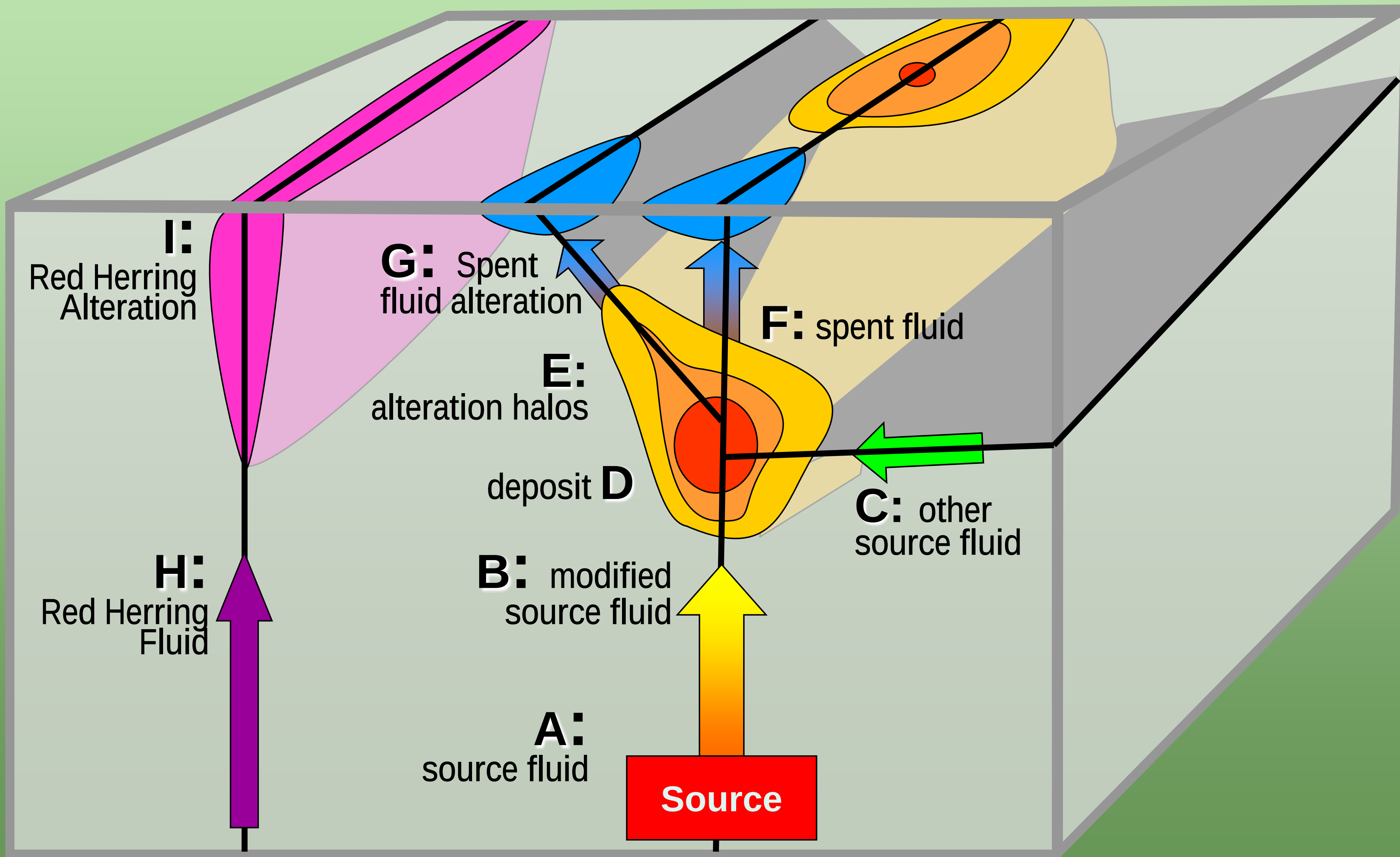




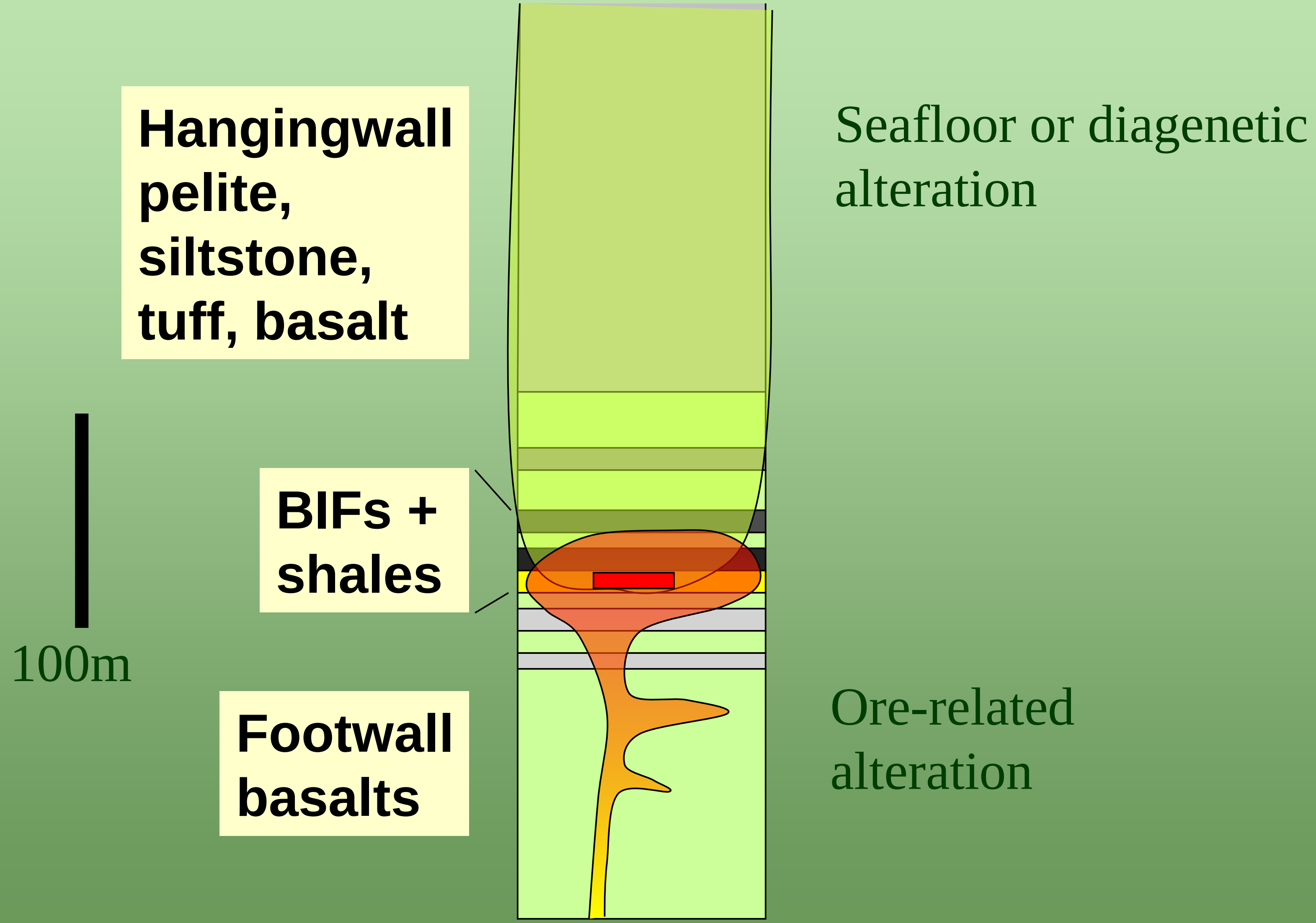



Com licença, onde está o ouro?

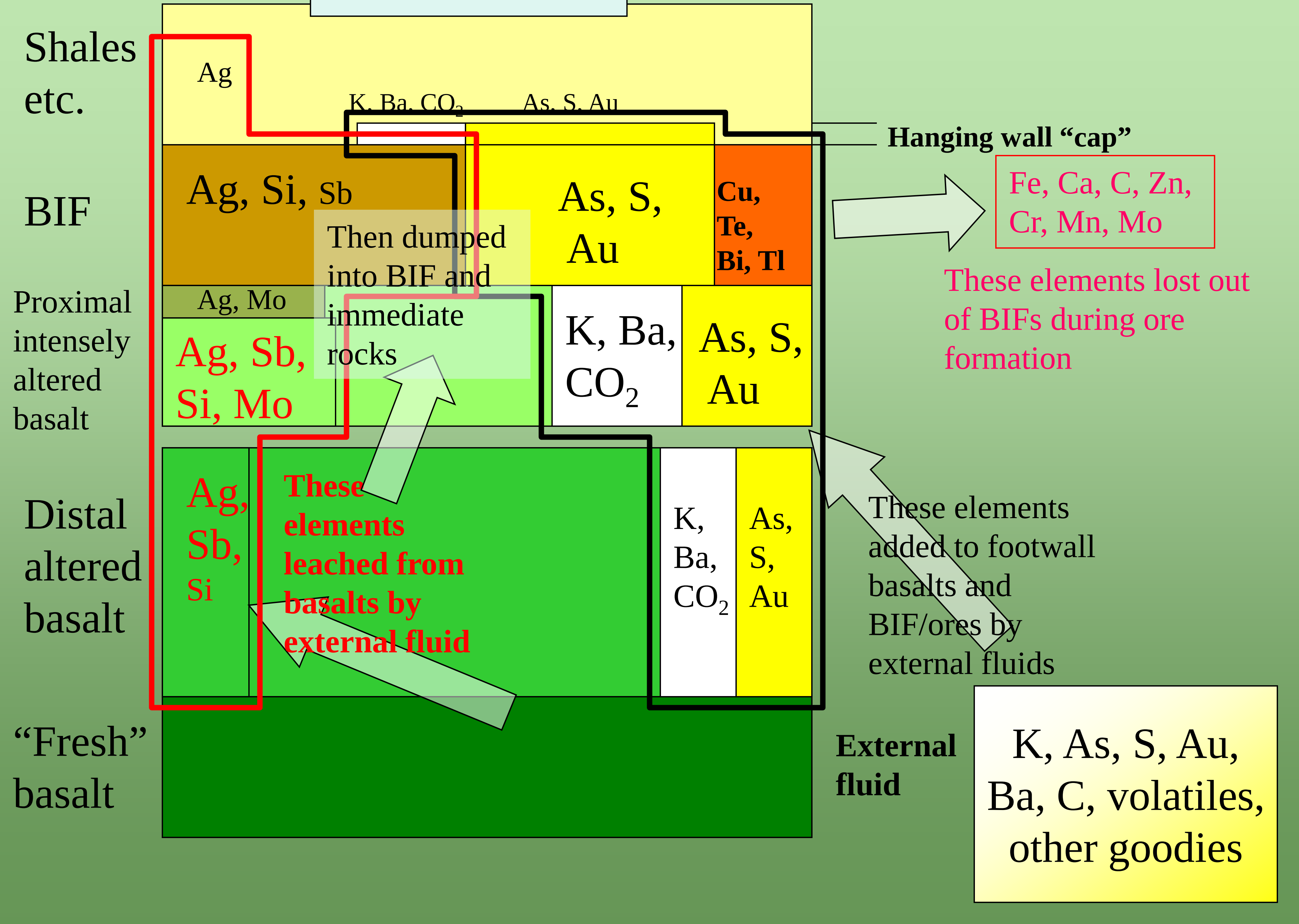
Use geochemistry to build up a conceptual chemical model for the ore system, based around the structural/temporal framework



Stratigraphy and alteration at Cuiabá

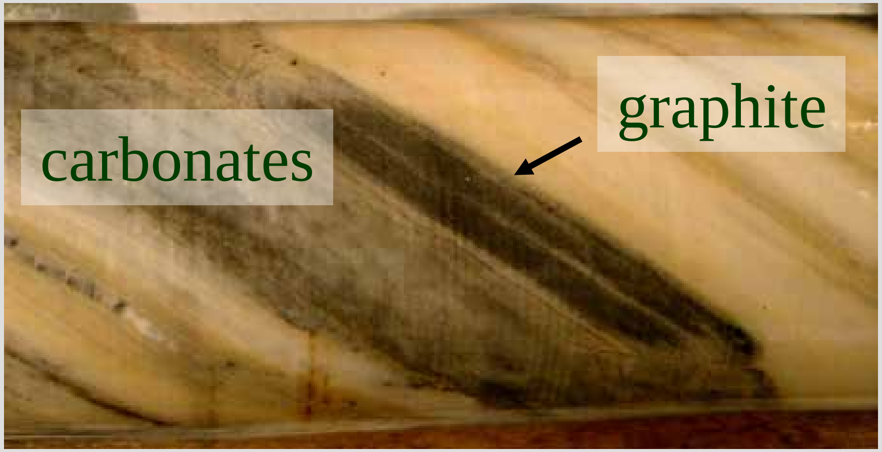


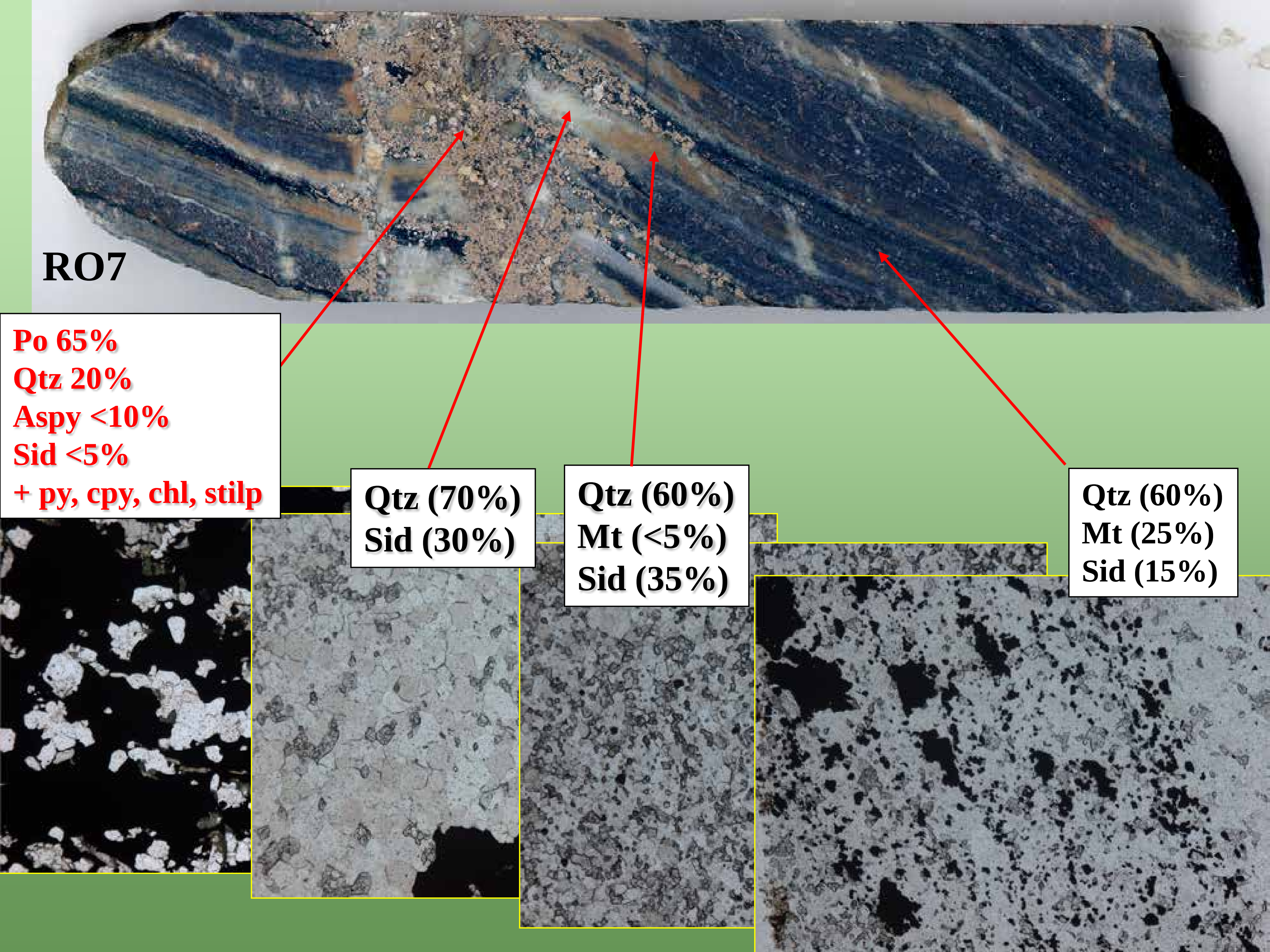
Losses vs Gains

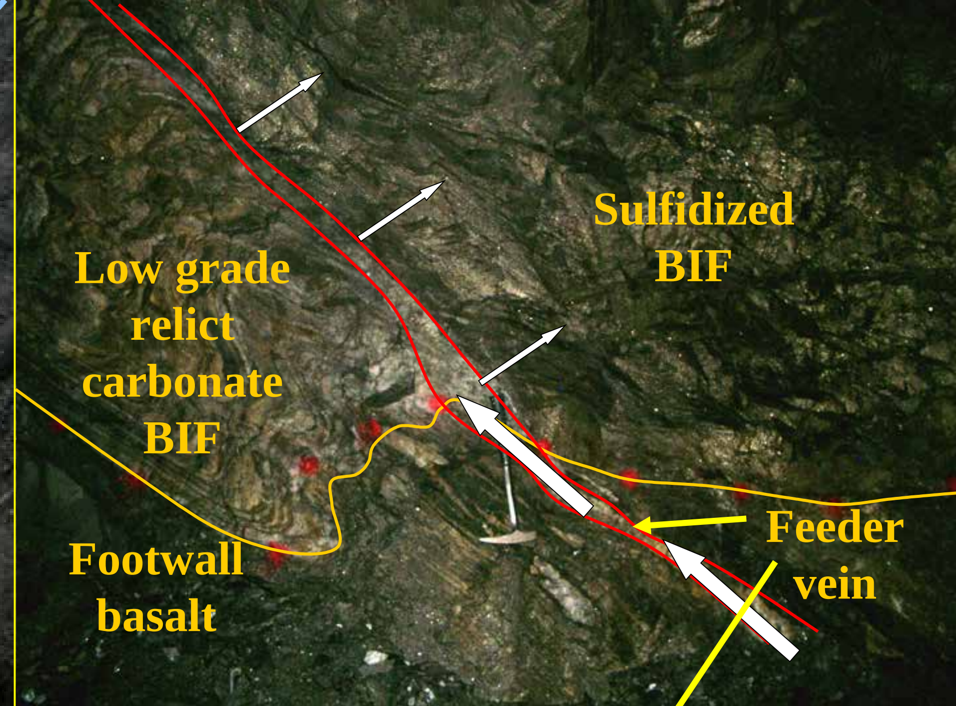


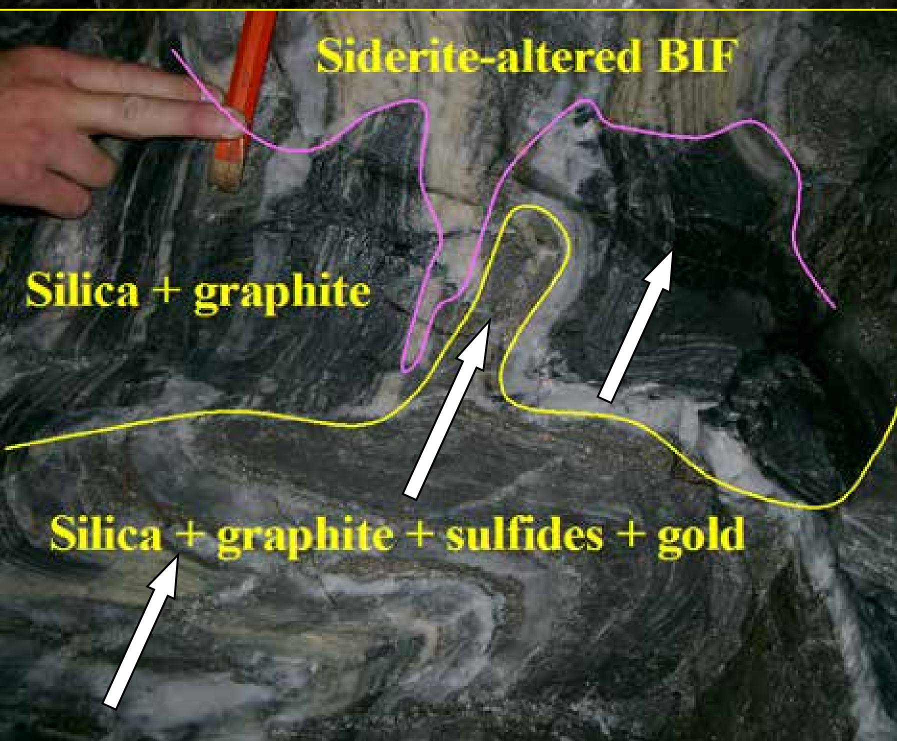
Key geochemical steps:

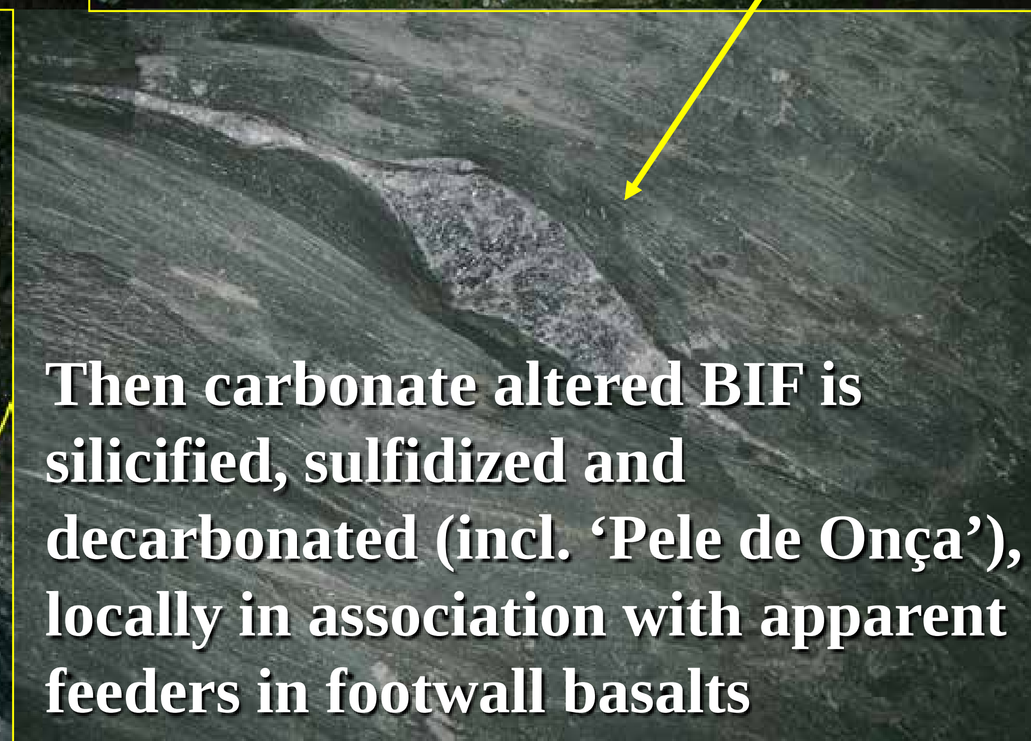
- In BIFs, graphite and magnetite get converted to carbonate, reducing the fluid




RO7
Po 65%
Qtz 20%
Aspy <10%
Sid <5%
+ py, cpy, chl, stilp
Qtz (70%)
Sid (30%)
Qtz (60%)
Mt (<5%)
Sid (35%)
Qtz (60%)
Mt (25%)
Sid (15%)

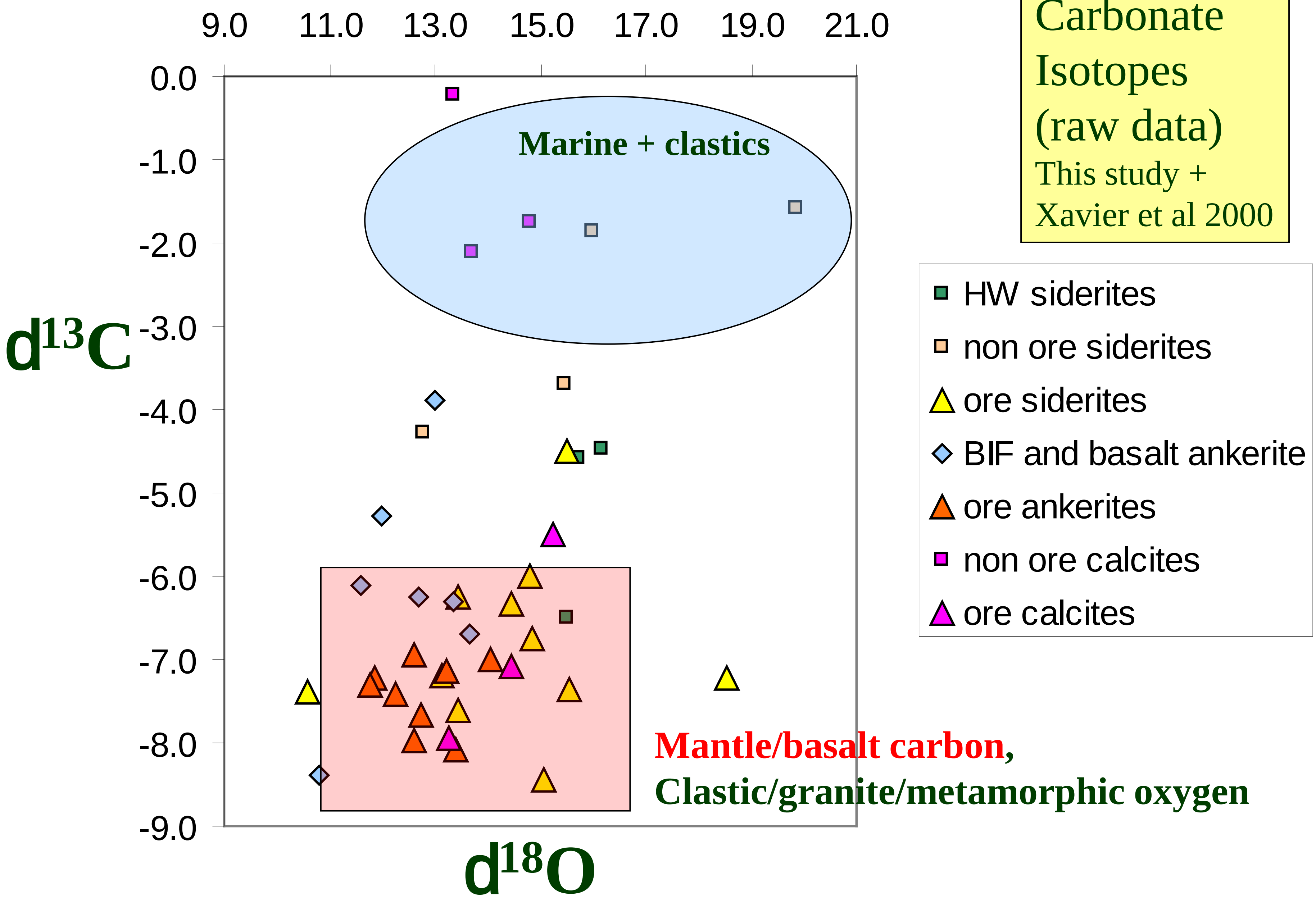






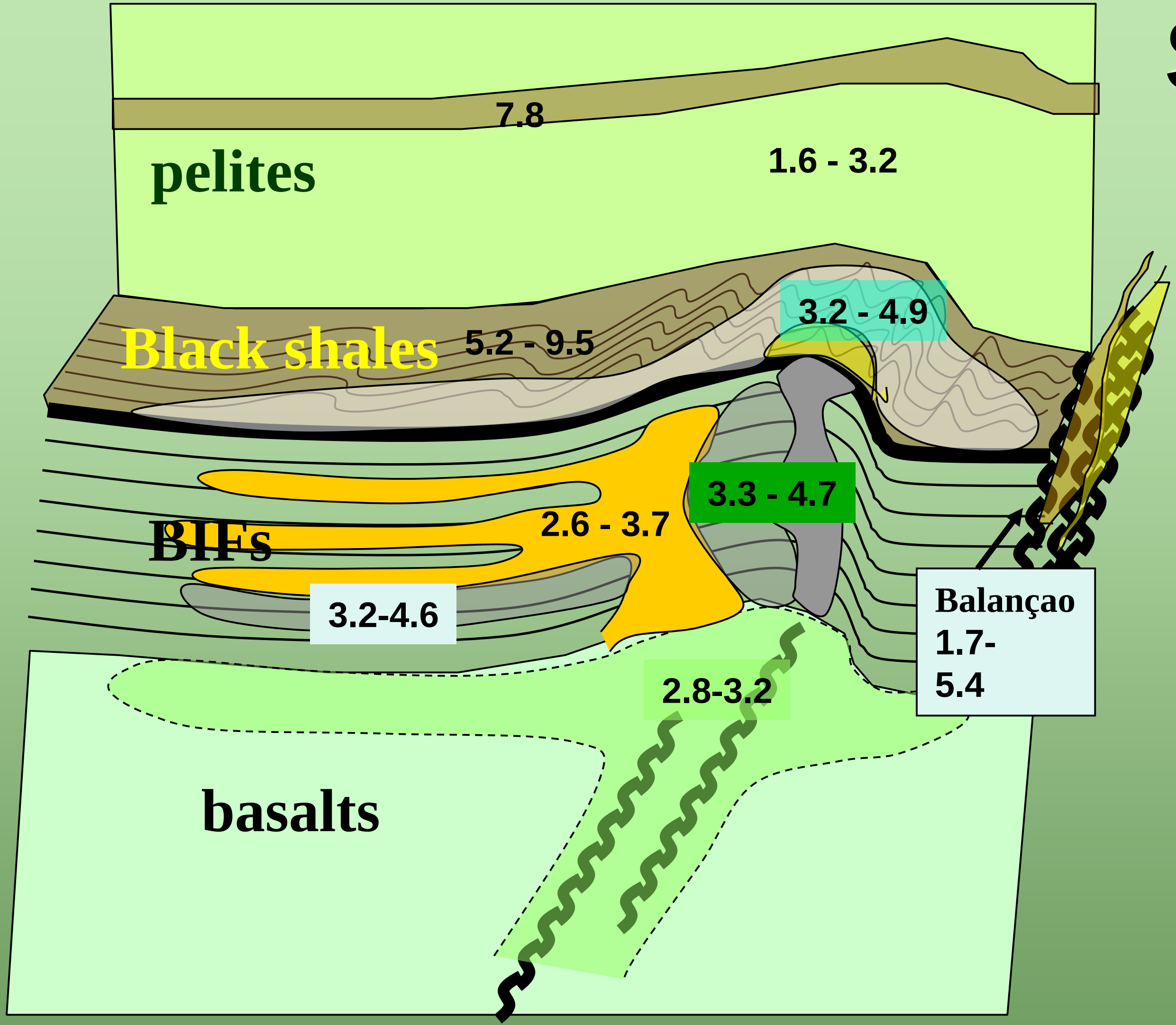
Then carbonate altered BIF is silicified, sulfidized and decarbonated (incl. 'Pele de Onça'), locally in association with apparent feeders in footwall basalts

What is the source of the fluid?

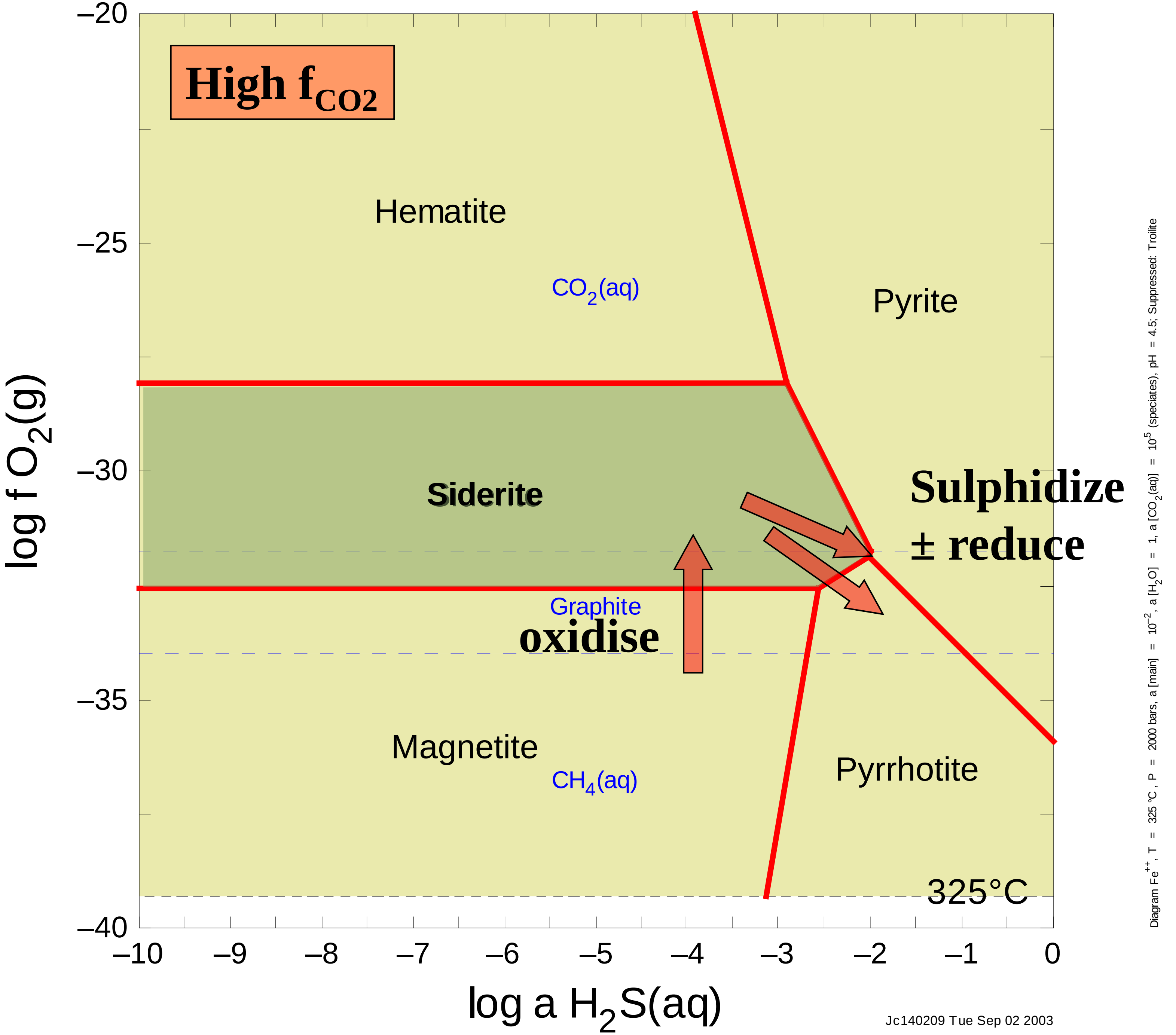


Carbonate Isotopes (raw data)
This study + Xavier et al 2000

S isotopes



- S in ores was derived from same source as in basalts
- S in black shales has influenced local ore d34S values
- But magmatic/basaltic S signature penetrates just into immediate hangingwall black shales - consistent with these shales acting as a cap
- Py-po abundance means that SO_4-H_2S fractionation effects can be ignored; i.e. d34S sulphides ≈ d34S fluid

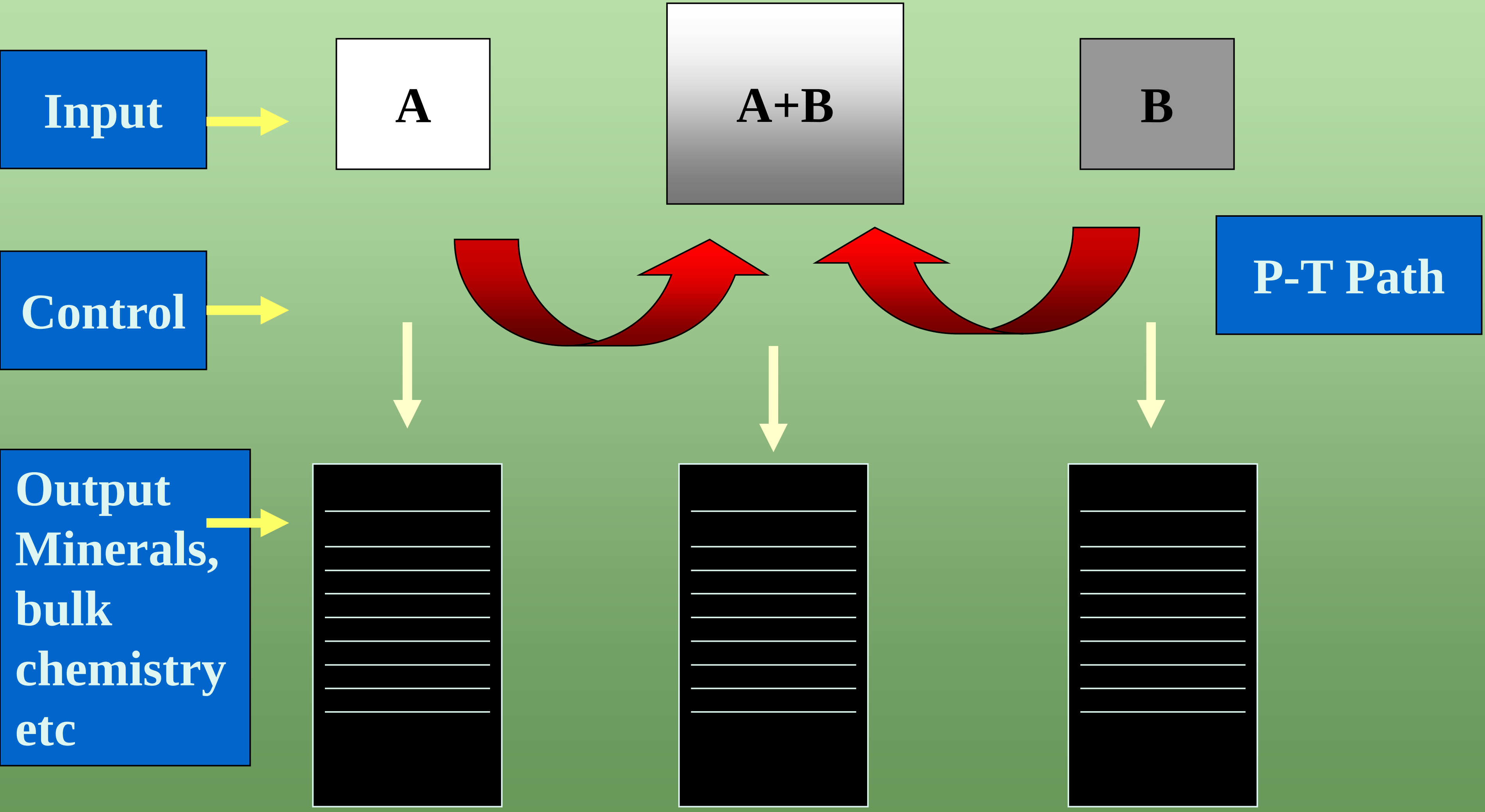

High f_{CO2}
Hematite
CO_2(aq)
Pyrite
Siderite
Sulphidize
± reduce
Graphite
oxidise
Magnetite
CH_4(aq)
Pyrrhotite
325°C
–20
–25
–30
–35
–40
–10
–9
–8
–7
–6
–5
–4
–3
–2
–1
0
log f O_2(g)
log a H_2S(aq)
Jc140209 Tue Sep 02 2003
Diagram Fe^{++}, T = 325 °C , P = 2000 bars, a [main] = 10^{-2}, a [H_2O] = 1, a [CO_2(aq)] = 10^{-5} (speciates), pH = 4.5; Suppressed: Troilite

HCh: geochemical modelling package

Advantages for ore deposit studies:

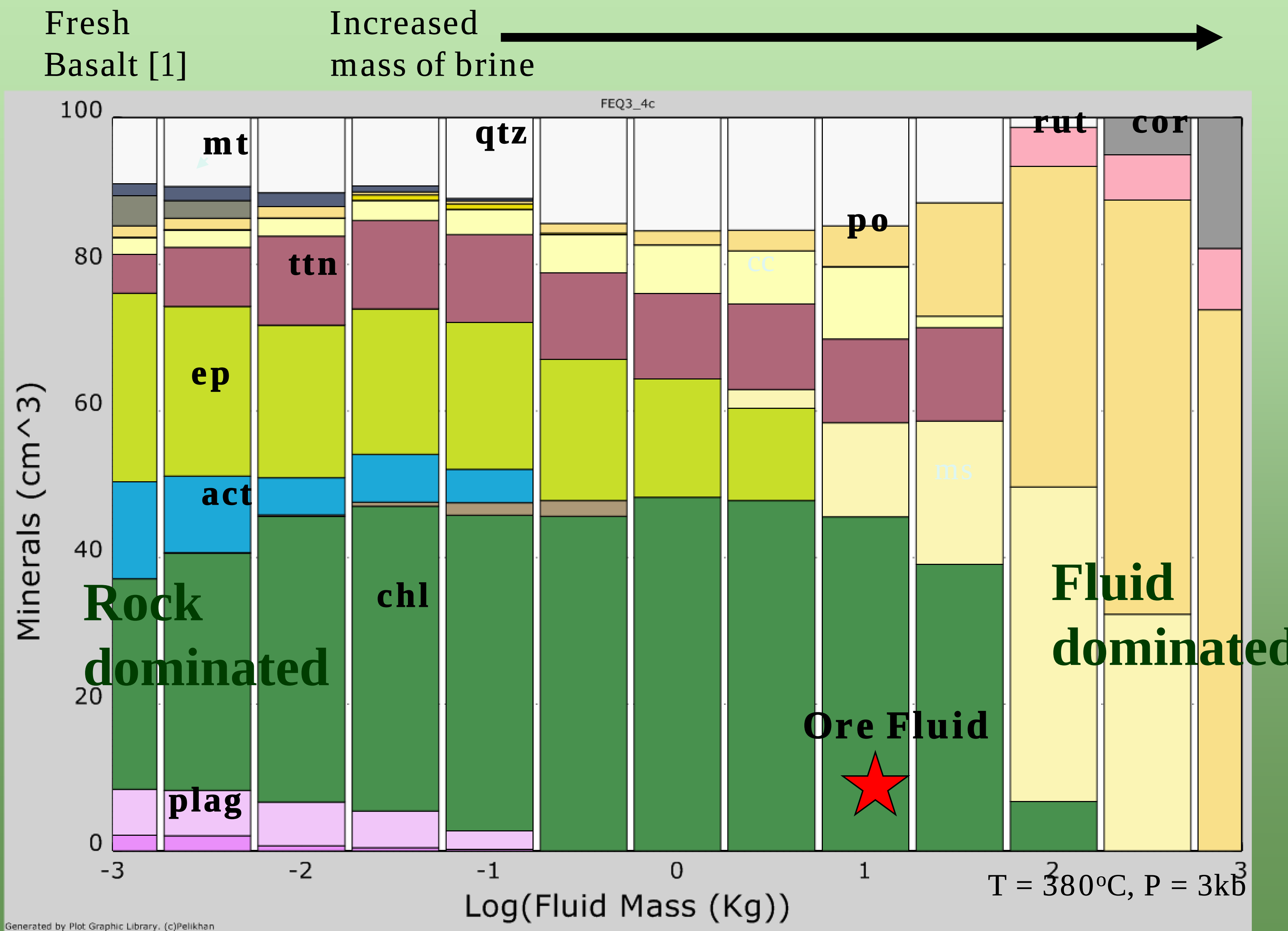
- Powerful and flexible algorithm generator that can be used to model a wide range of geological (fluid-rock) scenarios (up to 5 kbar, 1000°C)
- Well maintained high PT thermodynamic datatset that is available online (FreeGs).
- Thermodynamic data for wide range of metals, metal complexes and S.
- Close collaboration with code developer(s) that provides greater potential in future development directions – industry focus and user interface.

HCh concept

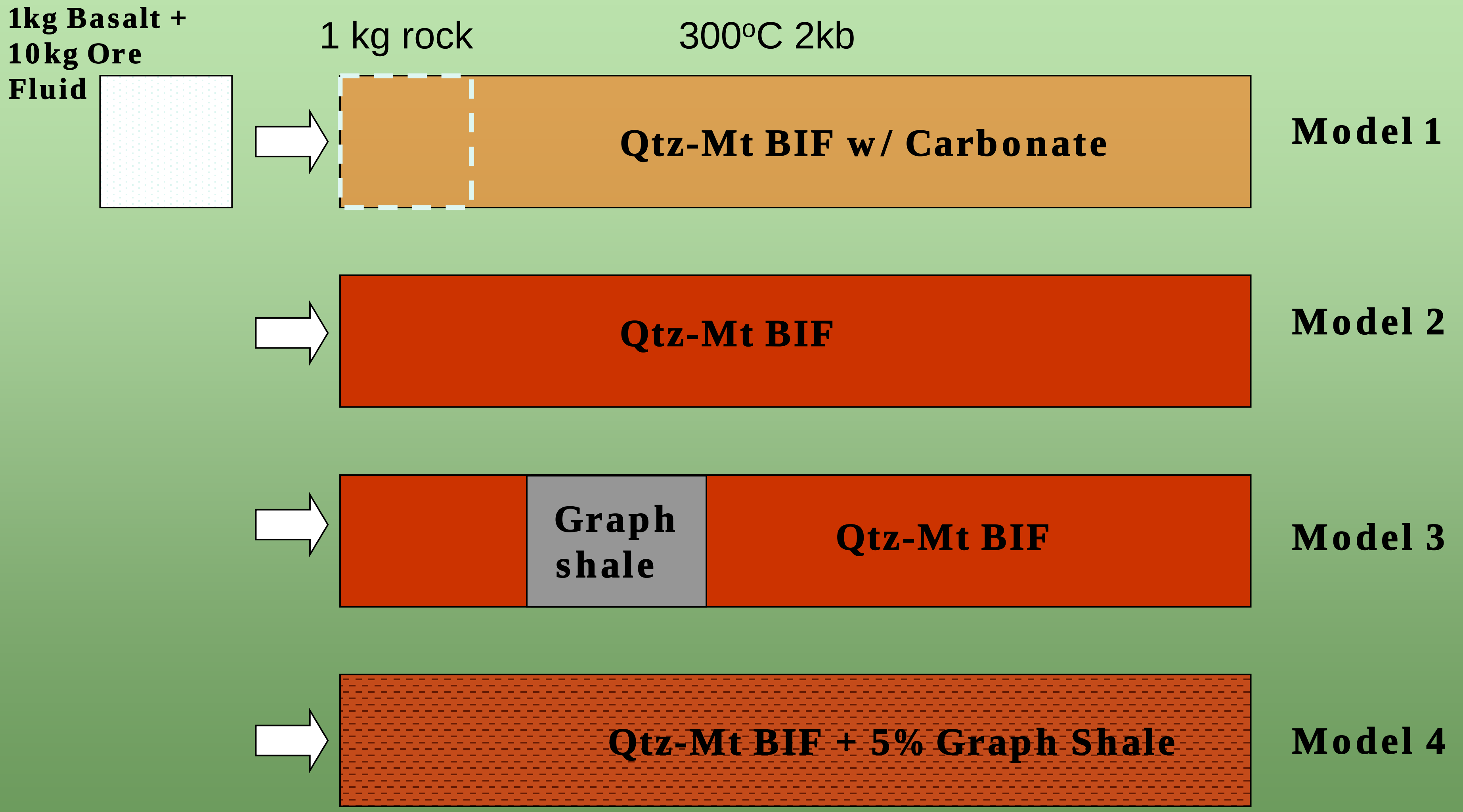


Input
A
A+B
B
Control
P-T Path
Output
Minerals,
bulk
chemistry
etc

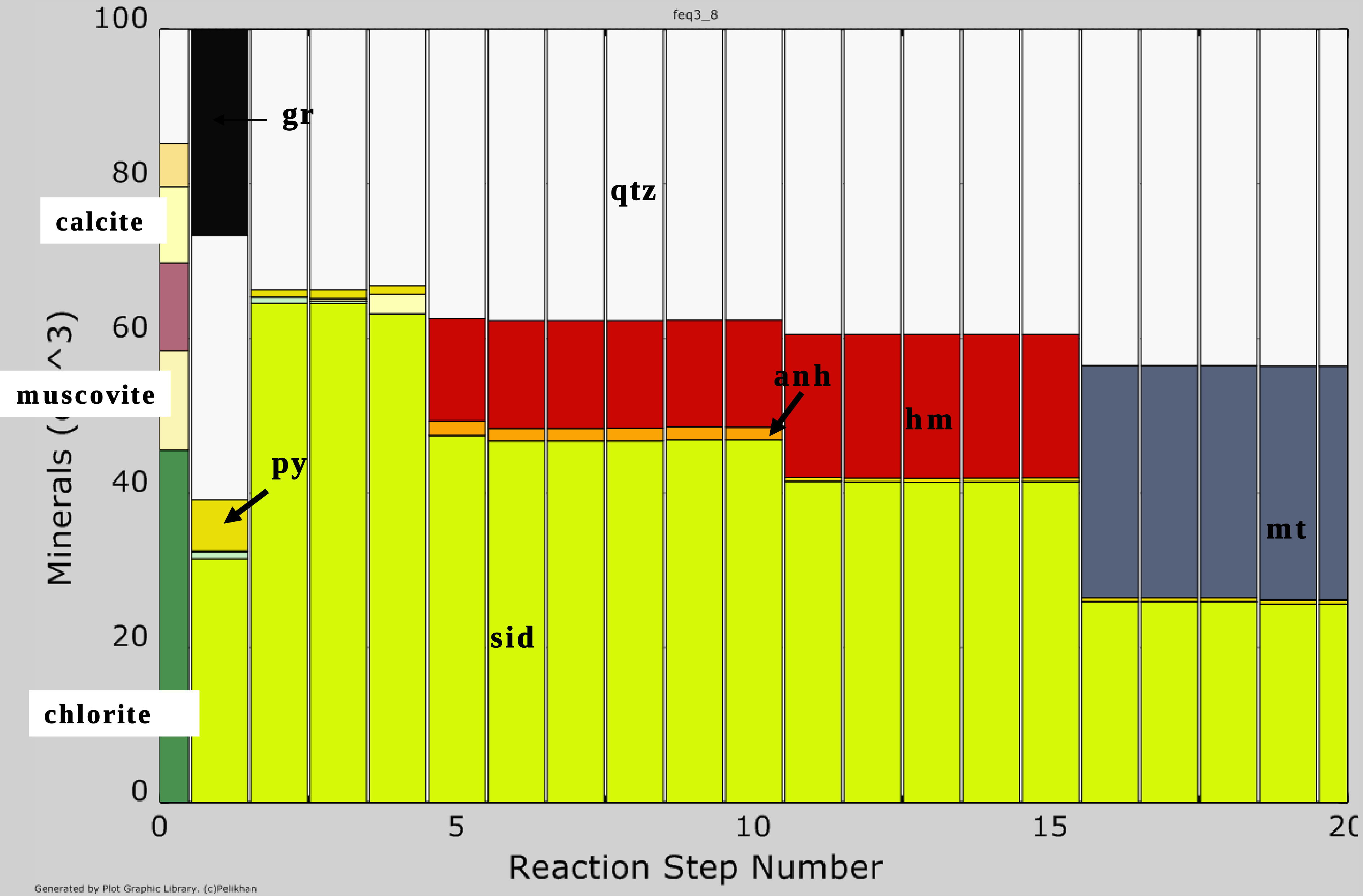
Creating an ore fluid: equilibrate a simple fluid with basalt – when assemblage matches, this is a possible ore fluid



BIF Alteration and Gold deposition

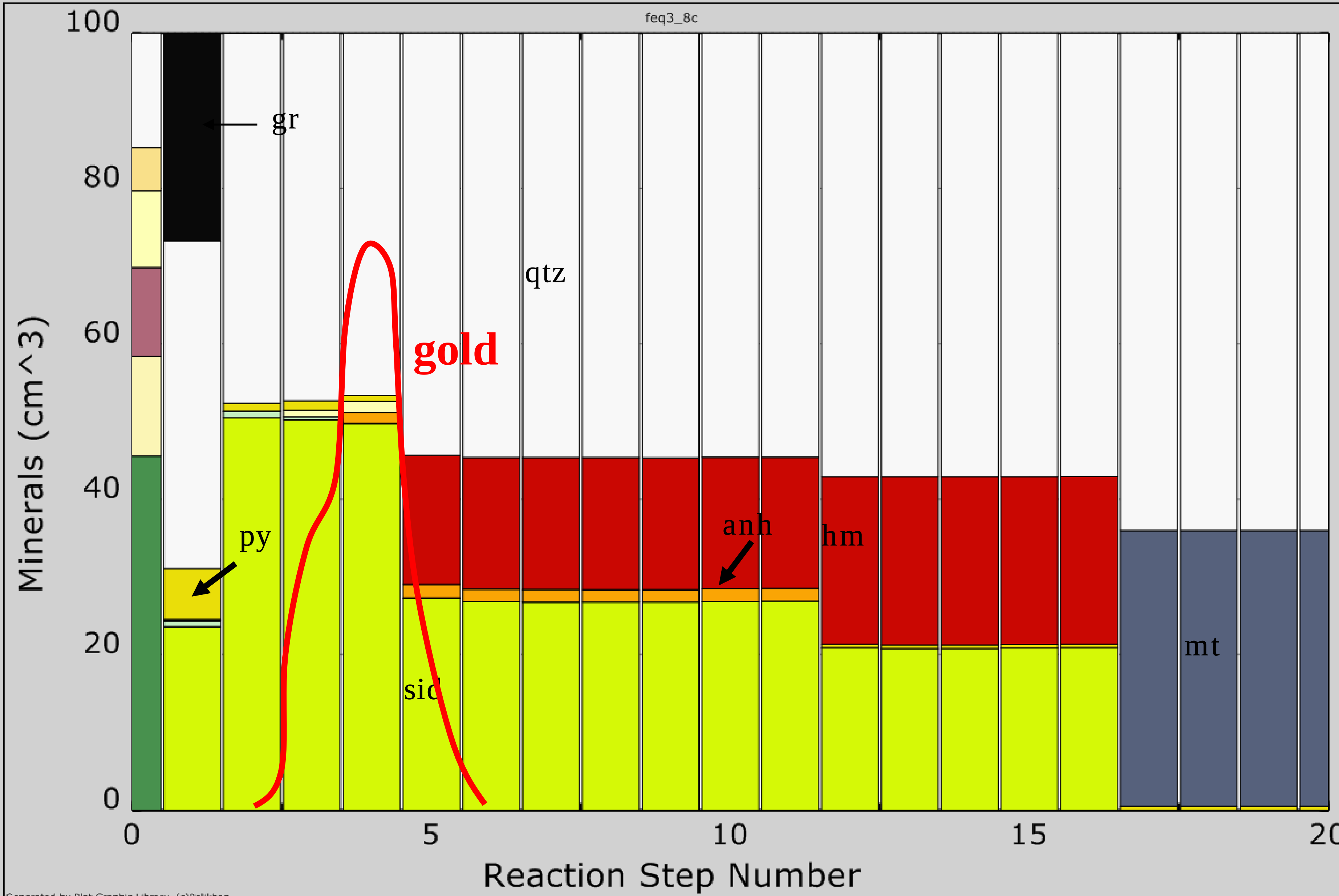


Model 1: Infiltration of pre-carbonated qtz-mt BIF

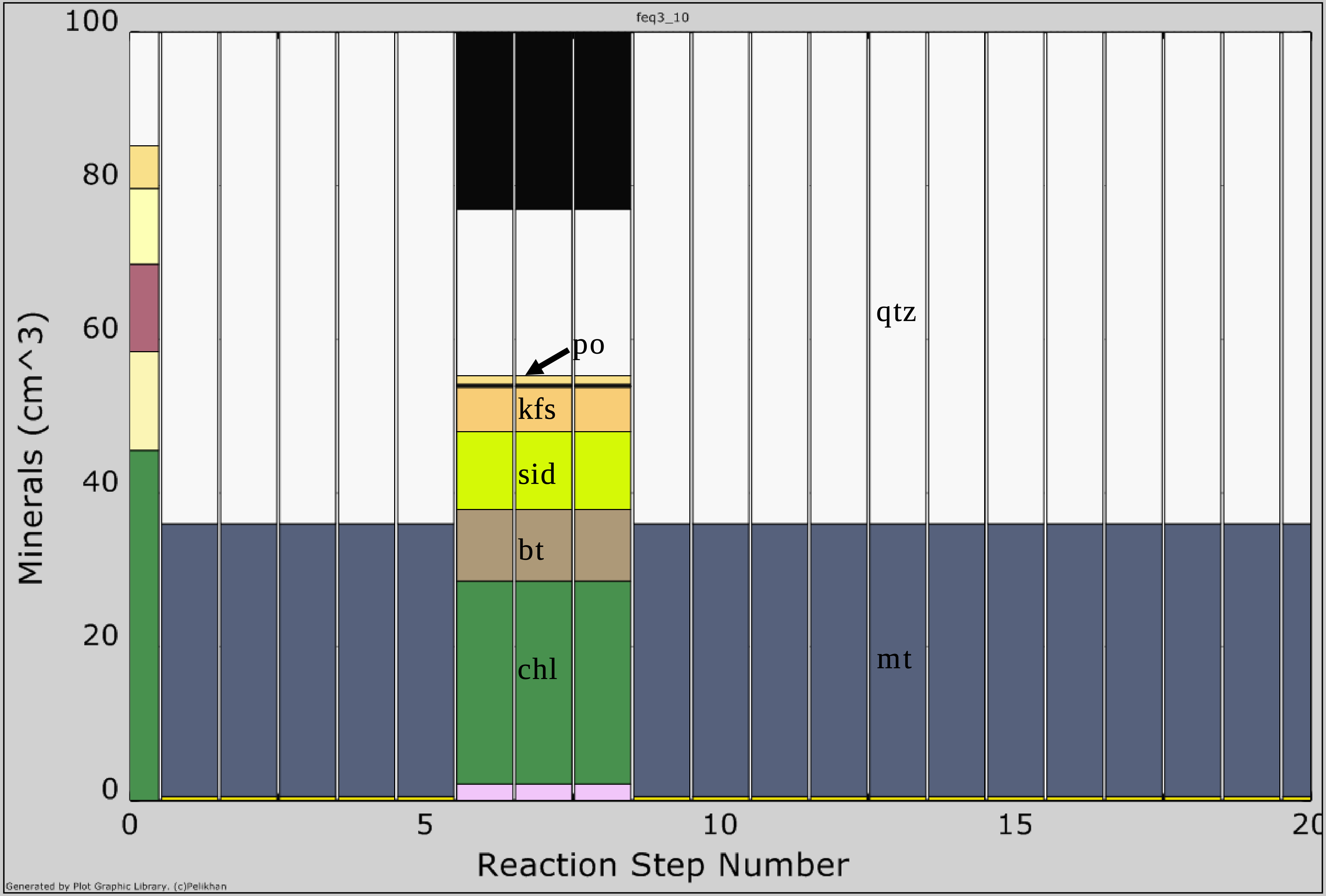


Model 2: Infiltration of fresh qtz-mt BIF (no pre-carbonate alteration)

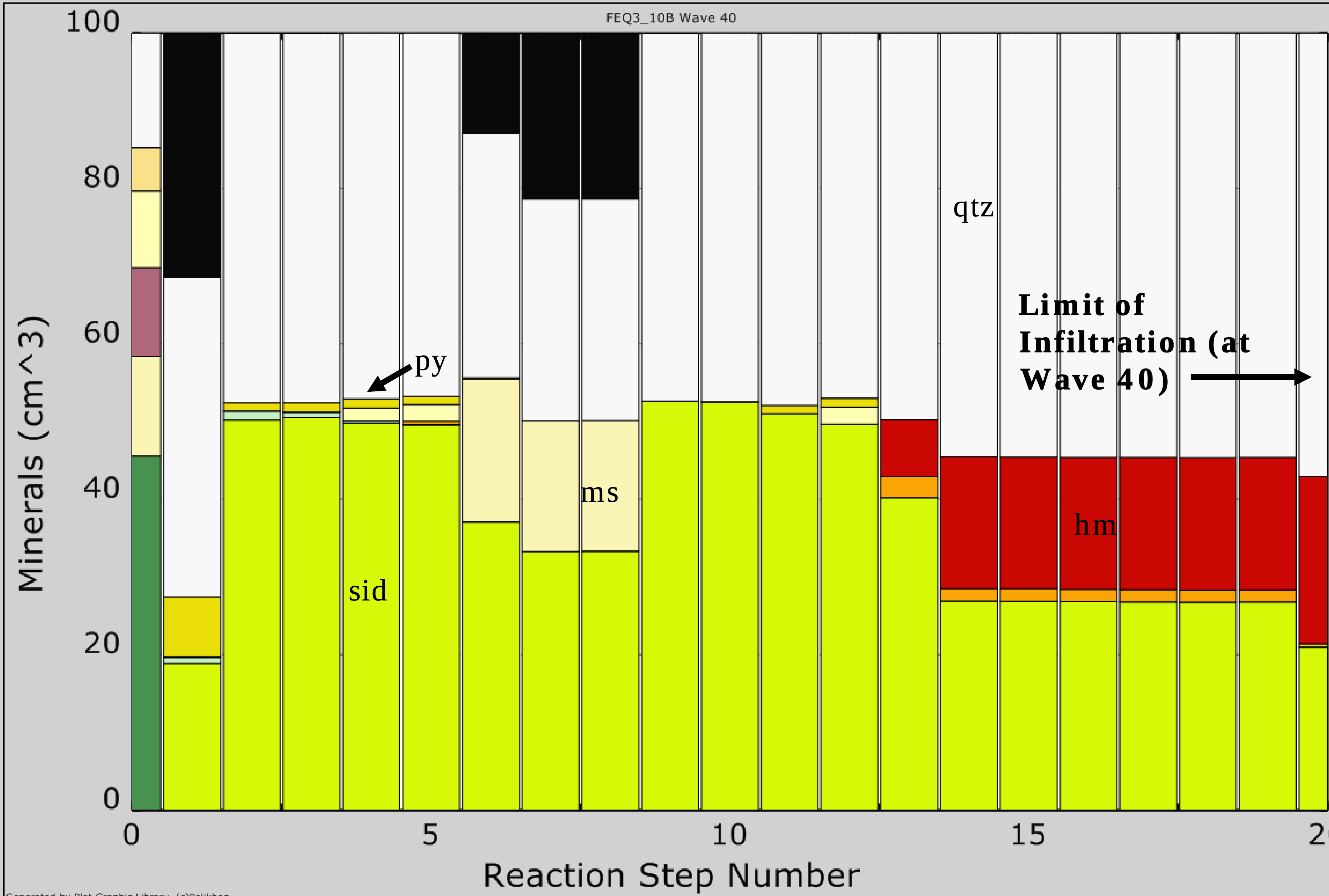
Gold



Model 3: Infiltration of fresh qtz-mt BIF with graphitic shale in middle



Model 3: Infiltration of fresh qtz-mt BIF with graphitic shale in middle

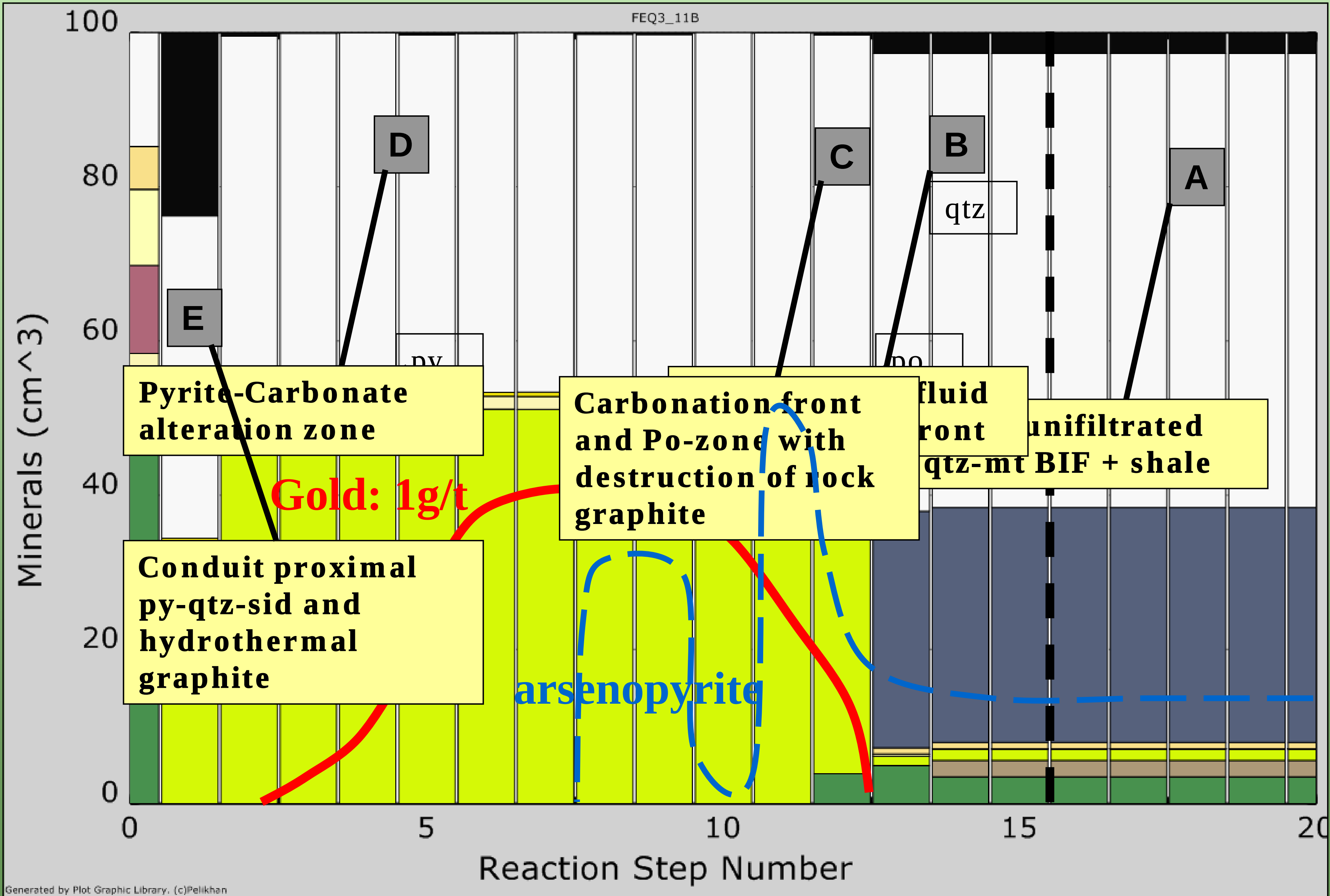


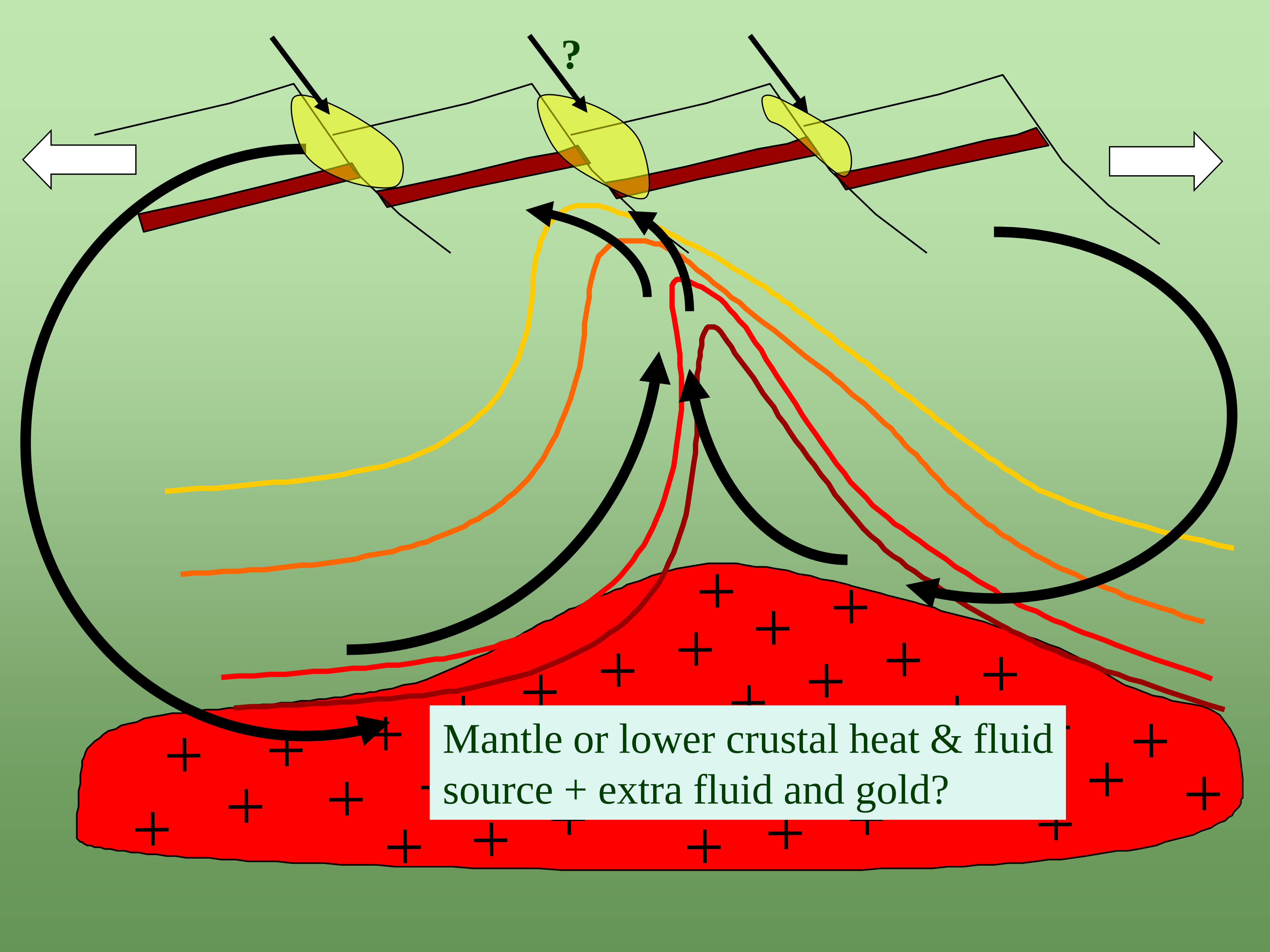
Model 4

- Infiltrate ore fluid through BIF with 5% graphitic shale distributed through out.
- Causes reduced assemblages throughout and without the oxidised assemblages at the most distal portion.
- Good match between model and reality but probably not enough sulfidation
- Extra sulfur – magmatic sulfur from depth?

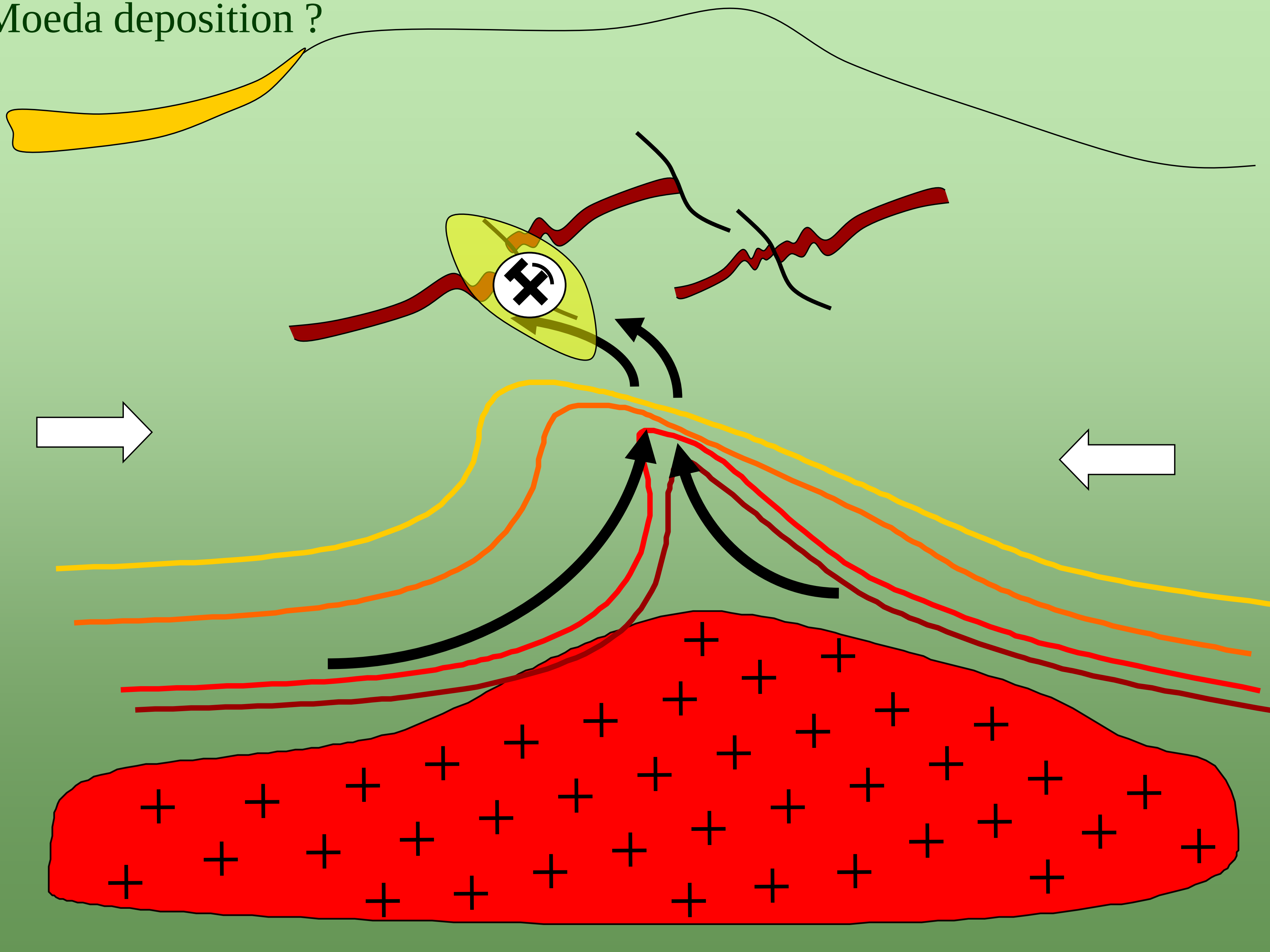
Model 4: Infiltration of fresh qtz-mt BIF mixed with 5% graphitic shale

Gold is lower grade and more distributed: need more sulfur and gold in fluid than modelled – extra source?




?
Mantle or lower crustal heat & fluid source + extra fluid and gold?

Moeda deposition ?



Key finding	**Potential impact on exploration and mine development**
Weak Ag anomalism detected in hangingwall sediments above Cuiabá and Lamego	*PIMA work on micas, with corresponding mineral chemistry (electron probe) should be trialled to see if a quicker exploration method exists for distal ore signals.*
K, As, S, Au, Ba, CO2 added to BIFs and proximal footwall basalts by external fluid; Ag, Sb and Si leached from distal footwall basalts; Fe, Ca, C, Zn, Cr, Mn, Mo lost from mineralized BIFs	Only useful for exploration in footwall basalts and BIFs; *PIMA/radiometrics for K alteration intensity and mica chemistry may be the cheapest method of detection.* High S and As also distinctive for both ore-proximal basalts and BIFs. Feeders are potentially recognisable at mine scales.
Geochemical models require intercalated black shales in BIF, S isotopes and geochem also indicate hangingwall black shales acted as a trap/cap	*Black shales are crucial.* These deposits must have good black shale association for high grade, otherwise the magnetite/siderite cannot cause sufficient sulfidation and gold deposition. *Black shale S isotopes (if BIF hasn't been detected in core but black shale has) could potentially indicate ore proximity: 5 to 10‰ = distal, 3 to 5‰ = proximal*

- **Main exploration outcome: recognise F1 hinges, then target BIFs with intimately associated graphitic schists**
- **Main mining outcome: recognition of feeder structures can help with prediction of down-plunge orebody extensions. Pay attention to graphitized BIF**

The end.